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Agricultural Research Administration
Bureau of Entomology and Plant Quarantine

USE OF INSECT REPELLENTS AND TOXICANTS ^{1/}

By B. V. Travis, F. A. Morton, and Carroll N. Smith,
Division of Insects Affecting Man and Animals

During the last several years thousands of chemicals have been tested to determine their value in repelling various kinds of insects. Out of this large number a few new repellents and toxicants have been developed which give effective protection from the bites of mosquitoes, punkies (no-see-ums), black flies and other biting flies, and chiggers, or red bugs (mites). Unlike the older repellents, these materials have little or no odor and they remain effective from two to several hours even when these insects occur in large numbers. This circular gives information on the availability, use, and effectiveness of these insect repellents and toxicants. Although they were developed primarily for military use, they can also be used safely by civilians.

Formulations

The following available repellents are effective and safe when used individually or in combination: Dimethyl phthalate, dimethyl carbate (dimethyl ester of cis-bicyclo [2,2,1]-5-heptene-2,3-dicarboxylic acid), Indalone (3,4-dihydro-2,2-dimethyl-4-oxo-butyl ester of 1,2H-pyran-6-carboxylic acid), and Rutgers 612 (2-ethyl-1,3-hexanediol). 2-Phenoxyethyl acetate is deemed safe for use individually, but its safety in various combinations has not been established.

These chemicals vary greatly in their effectiveness against different insects and on different individuals. Certain materials which are satisfactory against some species may fail to repel others. Laboratory and field tests have shown that the following mixtures of repellents are effective against a wider range of insect species and on more individuals than any one of the chemicals when used alone.

1/ The data included in this paper were obtained in connection with investigations conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development and from the National Military Establishment, Department of the Army, to the Bureau of Entomology and Plant Quarantine.

Formula 1

Dimethyl phthalate - 3 parts 2/
Indalone----- 1 part
Rutgers 612----- 1 part

Formula 2

Dimethyl phthalate - 1 part
Indalone----- 1 part
Rutgers 612----- 1 part

Formula 3

Dimethyl phthalate - 3 parts
Indalone----- 1 part
Dimethyl carbate--- 1 part

Mixtures containing two repellents are also fairly effective, but these do not repel so wide a range of insects or for so long periods as do the triple mixtures. Examples of such mixtures are:

Formula 4

Dimethyl phthalate - 2 parts
Rutgers 612 ----- 1 part

Formula 5

Dimethyl phthalate - 2 parts
Dimethyl carbate--- 1 part

Some of the repellents that are now offered for sale under proprietary or trade names contain only a small percentage of the active ingredient and a large percentage of alcohol or some other diluent. Although such materials have physical properties that make them more acceptable cosmetically, the period of protection is much reduced by the addition of the diluent. For maximum protection the chemicals should not be diluted with inert materials.

Effect of Application to the Skin

These chemicals and some of their mixtures have been tested by toxicologists and have been found safe for use as skin applications. They are toxic if taken internally. Other chemicals have shown marked repellent qualities, but they cannot be recommended because of their irritating properties. Occasionally there are people who are allergic to certain of the materials that have passed toxicological tests. It is possible that a few persons may show slight rash or other minor skin reactions to some of the repellents. Any of the effective and toxicologically safe repellents may cause some "smarting" when applied to the mucous membranes and to areas where the skin is especially tender, such as the eyelids or groin region or where there are skin abrasions.

2/ All parts by weight.

CARE SHOULD BE TAKEN NOT TO APPLY ANY OF THE APPROVED MATERIALS TOO LIBERALLY ON THE FOREHEAD OR EYELIDS, AS THEY CAUSE A RATHER SEVERE BUT TEMPORARY STINGING IF THEY GET INTO THE EYES. There will be a period after application when the treated skin will feel warm, especially if the skin is moist with sweat. Ordinarily the sensation lasts for only a few minutes and causes no injury.

Effect on Paints, Plastics, and Other Synthetic Materials

All these repellents are solvents of paints, varnishes, and many of the plastics. They must be used with caution, as they will damage such materials as plastic watch crystals, synthetic cloth (sharkskin, rayons, etc.) fingernail polish, and articles that are painted or varnished or made of plastics. These chemicals will not damage cotton or wool cloth if such cloth contains no synthetic fibers.

Use Against Mosquitoes, Flies, and Biting Gnats

Repellents must be uniformly distributed over the area to be protected. Otherwise the insects will seek out and bite in any small area where the repellent was not thoroughly applied.

Application to skin.--All these repellents feel oily on the skin and for this reason may be objectionable to use. However, materials of this type give more complete and longer protection than do the less viscous materials, which either evaporate or are absorbed shortly after application. Because the conditions of use are variable, the only rule to follow is to apply when the insects resume biting on the treated areas. Under favorable conditions one treatment may last several hours on some people, and not so long on others.

The most common method of using repellents from the bottle is to shake a few drops into the palms, smear evenly, and then apply thoroughly to the backs of the hands, wrists, neck, ears, face, or any other exposed skin, much as in washing. This procedure should be repeated until a uniform oily film is applied.

Application to clothing.--In some localities mosquitoes cause considerable annoyance by biting through clothing. Under such conditions repellents may be sprayed or daubed on clothing where the bites occur. This treatment may be expected to last several days if the clothing remains dry. One soaking with water, however, removes enough of the repellent to make treated clothing noneffective. (See Effect on Paints, Plastics, and Other Synthetic Materials).

A simple method of applying repellents to clothing is to shake about a dozen drops of the repellent from the bottle into one hand, rub the hands together, and rub lightly on socks, shirts, or trousers where bites occur. Repeat this procedure until the areas to be treated have been

covered. The repellents may be applied to the clothing also with a small hand sprayer. Spray lightly the areas where the insects are biting through the clothing.

Shirts, stockings or other garments may be treated by saturating them with solutions or emulsions of the repellents, as described in the next paragraph on use against chiggers. The repellents that provide the most durable treatments of clothing are 2-ethyl-2-butyl-1,3-propanediol, Indalone, and n-hexyl mandelate. The first compound is a solid at low temperatures, and is not recommended for application to the skin. It is deemed safe for application to the clothing at a rate of 1/4 ounce per square foot of cloth but need not be applied in excess of 1/10 ounce per square foot. Garments treated with these repellents will remain effective through 2 or 3 days of ordinary wear, but not after washing or prolonged soaking in water.

Use Against Chiggers or Red Bugs (Mites)

Any of the insect repellents mentioned will give protection from chigger bites if properly applied. The action on chiggers is largely as a toxicant, which kills them, rather than as a repellent. The materials should be applied to the clothing rather than to the skin. Re-treatment is necessary after washing or soaking in water. In addition to the toxicants mentioned, benzyl benzoate, diphenyl carbonate, and benzil are very effective. Clothing treated with benzyl benzoate will remain effective after two ordinary home launderings, and diphenyl carbonate and benzil after five or more washings. The last two compounds are solids, and must be applied as solutions in dry cleaning fluids or as dusts.

The methods of applying these chemicals for protection against chiggers vary according to the needs of the individual.

Hand application.--The best and simplest method for the individual to treat his own clothing is to pour about a dozen drops of a liquid toxicant into one hand, rub the hands together, and then rub lightly on the socks and other clothing. The most liberal applications should be made along all openings of the clothing, such as inside the neckband, and the fly and cuffs of trousers.

Barrier method.--With the barrier method the liquid materials are applied only to the openings of the clothes--inside the neckband, fly, and cuffs of shirt; inside the waistband, fly, and cuffs of trousers; and on the socks both above the shoes and inside, below the tongue. The material may be applied by daubing as described above, with a sprayer, or by drawing the mouth of the bottle along the cloth to apply a thin layer one-half inch wide. Women's clothing may be protected in the same general way.

If one is not going to be crawling about on the ground, nearly complete protection can be obtained by smearing the acaricide only on the socks above the shoe tops and on the bottoms of the trouser legs.

Spray method.--The material may be applied to the clothing by the spray method described for protection from mosquito bites, except that special precautions should be taken to spray the openings to the clothes.

Dust method.--The solid acaricides may be applied to the clothing as 5-percent dusts, 2 to 3 ounces being required to treat the entire inner surface of a jacket, trousers, and socks. Only the socks and trousers need be treated if contact with the chigger-infested ground and vegetation will be restricted to the feet and legs. Re-treatment will be required each day of exposure. Sulfur dust used in this manner will also provide protection, but should be applied to the skin of the legs and arms as well as to the clothing.

Immersion method.--Complete protection can be obtained by immersing field clothing in a solution or water emulsion of the acaricide. Benzyl benzoate, benzil, or diphenyl carbonate are preferable for this purpose, as treatments with these compounds are more resistant to leaching by water. About 1/15 ounce of toxicant per square foot of cloth should be used, or 2 ounces to a jacket, trousers, and socks of medium size. The underwear need not be treated. The toxicant may be dissolved in enough dry cleaning fluid to wet the garments thoroughly without leaving any excess, about 1 1/2 quarts for an outfit of heavy cotton cloth. After all parts of the garments have been saturated with the solution, the cleaning fluid should be allowed to evaporate, leaving the cloth impregnated with the toxicant. The liquid acaricides may also be applied to the clothing as emulsions.

Although satisfactory emulsions can be made with soap, the most practical method is to prepare a concentrate by dissolving one of the following emulsifiers in the acaricide, using 10 parts $\frac{2}{3}$ of the emulsifier to 90 parts of the toxicant: Stearate 61-C-2280 (a polyalkylene glycol stearate); Tween 60 (sorbitan monostearate, polyoxyalkylene derivative); Tween 80 (sorbitan monooleate, polyoxyalkylene derivative); polymerized glycol monostearate, monooleate, or monolaurate; Span 60 (sorbitan monostearate) and Tween 60, equal parts; Span 80 (sorbitan monooleate) and Tween 80, equal parts.

The final emulsion in which the clothing is dipped can be prepared by adding 1/2 pint of the concentrate to 1 gallon of water. It is best to agitate vigorously 1 part of the concentrate in 2 or 3 parts of water to form a creamy emulsion and then dilute with the remainder of water, using moderate agitation. One gallon of emulsion is sufficient to dip a set of field trousers, shirts, and socks. After dipping, wring out the garments lightly and dry before wearing.

Use Against Ticks

None of the repellents or toxicants deemed safe for use will provide complete protection from ticks, but several of them will afford a high degree of protection against the most abundant pest species, the lone

star tick. The socks and all the outer clothing should be treated by the immersion method described under use against chiggers. The best repellents for use against ticks, in order of preference, are n-hexyl mandelate, Indalone, dimethyl carbate, 2-ethyl-2-butyl-1,3-propanediol, diethyl phthalate, dimethyl phthalate, and benzyl benzoate. Other, more effective, compounds are still being studied for their toxicity to mammals, and may eventually be released for general use. Treated clothing remains effective through several days of ordinary wear, but not through washing.

Sources of Materials

The following list of firms which may supply the materials mentioned above is given for the information of the reader. It does not include all firms, and no discrimination is intended or implied for names omitted, nor is warranty given as to the grade or standard of the product of these firms.

Finished Repellents and Mixtures

Carbide and Carbon Chemicals Corp., Fine Chemicals Division,
30 E. 42nd St., New York, N. Y.

The J. B. Williams Co., 420 Lexington Ave., New York, N. Y.

U. S. Industrial Chemicals, Inc., 60 E. 42nd St., New York, N. Y.

Repellents

Benzil

Eastman Kodak Company, Organic Chemical Sales Division,
Rochester, N. Y.

Benzyl benzoate

Practically any large chemical firm or your local druggist.

2-Butyl-2-ethyl-1,3-propanediol

Carbide & Carbon Chemical Corp., Fine Chemicals Division,
30 E. 42nd St., New York, N. Y.

Diethyl phthalate

Practically any large chemical firm or your local druggist.

Dimethyl carbate

Sowa Chemical Co., 305 E. 46th St., New York, N. Y.
U. S. Industrial Chemicals, Inc., 60 E. 42nd St., New York, N. Y.

Dimethyl phthalate

Practically any large chemical firm or your local druggist.

Diphenyl carbonate

Allied Chemical & Dye Corp., General Chemical Division,
40 Rector St., New York, N. Y.

n-Hexyl mandelate

Carbide & Carbon Chemicals Corp., Fine Chemicals Division,
30 East 42nd St., New York, N. Y.

Indalone

Kilgore Chemicals, Inc., 1050-30th St., N. W., Washington, D. C.
U. S. Industrial Chemicals, Inc., 60 E. 42nd St., New York, N. Y.

2-Phenoxyethyl acetate

Dow Chemical Co., Technical Service & Development Division,
Midland, Mich.

Rutgers 612

Carbide & Carbon Chemicals Corp., Fine Chemicals Division,
30 E. 42nd St., New York, N. Y.

Emulsifiers

Polymerized glycol monolaurate, monostearate, and monooleate

Glyco Products Co., Inc., 26 Court St., Brooklyn, N. Y.

Spans and Tweens

Atlas Powder Co., 9th and Market Sts., Wilmington, Del.

Stearate 61-C-2280

Carbide & Carbon Chemicals Corp., Fine Chemicals Division,
30 E. 42nd St., New York, N. Y.

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